DIVISION 700 - MATERIALS

SECTION 702 -- BITUMINOUS MATERIALS

Table 2 -- Anionic Asphalt Emulsion (Metric)

Type	Rapid-Setting									
Grade	RS-1		RS-2		HFMS-2		MS-4		MS-5	
	min	max	min	max	min	max	min	max	min	max
Tests on emulsions: Viscosity, Saybolt Furol at 25 °C, s	20	100			100 see (1)		50	500	50	500
Viscosity, Saybolt Furol at 50 °C, s			75	400						
Storage stability test, 24-h, %		1		1		1		1		1
Coating ability and water resistance:										
Coating, dry aggregate					good		75+		75+	
Coating, after spraying					fair		see (2) (3) (4)		see (2) (3) (4)	
Coating, wet aggregate					fair					
Coating, after spraying					fair					
Sieve test, %		0.10		0.10		0.10		0.10		0.10
Oil Distillate, %							2.0	7.0	0	3.0
Residue by distillation, %	55		63		65		65		65	
Tests on residue from distillation test: Penetration, 25 °C, 100 g, 5 s	100	200	100	200	100	200	200		150	250
Solubility in trichloroethylene, %	97.5		97.5		97.5		97.5		97.5	
Float test, 60 °C, s					1200		50		100	

Numbers in parenthesis refer to notes on page 4.

SECTION 702

Table 2E -- Anionic Asphalt Emulsion (English)										
Type	Rapid-Setting									
Grade	RS-1		RS-2		HFMS-2		MS-4		MS-5	
	min	max	min	max	min	max	min	max	min	max
Tests on emulsions:										
Viscosity, Saybolt Furol at 77 °F s	20	100			100 see (1)		50	500	50	500
Viscosity, Saybolt Furol at 122 °F, s			75	400						
Storage stability test, 24-h, %		1		1		1		1		1
Coating ability and water resistance:										
Coating, dry aggregate					good		75+		75+	
Coating, after spraying					fair		see (2) (3) (4)		see (2) (3) (4)	
Coating, wet aggregate					fair					
Coating, after spraying					fair					
Sieve test, %		0.10		0.10		0.10		0.10		0.10
Oil Distillate, %							2.0	7.0	0	3.0
Residue by distillation, %	55		63		65		65		65	
Tests on residue from distillation test:										
Penetration, 77 °F, 100 g, 5 s	100	200	100	200	100	200	200		150	250
Solubility in trichloroethylene, %	97.5		97.5		97.5		97.5		97.5	
Float test, 140 °F, s					1200		50		100	

Numbers in parenthesis refer to notes on page 4.

TABLE 2 -- ANIONIC ASPHALT EMULSIONS
(continued)

(1) 50 + when material is used for sealing.

(2) Wet Coating: Weigh 100 ± 0.5 g of aggregate, 0.85 to 0.60 mm (20 to 30 mesh) standard Ottawa sand, into a 600 mL glass beaker and add soft tap water, approximately twice the volume of that of sand. Weigh into the beaker containing the sand and water 8 ± 0.2 g of the emulsion at room temperature and mix for two minutes with a stiff spatula. Cover the mixture with approximately twice its own volume of tap water and pour the water off without further mixing. Repeat this process. After the second rinse, at least 75 percent of the sand shall remain coated.

(3) Stripping: After evaluating the wet coating, place the mixture into a clear 600 mL glass beaker, cover the mixture with tap water, let stand for 12 to 16 hours, and examine. At least 75 percent of the sand shall remain coated.

(4) The coating and stripping tests may be waived when MS-5 is used for sand sealing.
SECTION 703 -- AGGREGATES

Table 1 -- Required Grading, Graded Coarse Aggregates (Metric)

Standard Stone Size	#4	#357	#467	#57	#67	#7	#89
Min to Max, mm	19.0 to 37.5	4.75 to 50	4.75 to 37.5	4.75 to 25.0	4.75 to 19.0	4.75 to 12.5	1.18 to 9.5
Sieve Size	Percentage by Weight Passing						
63 mm	---	100	---	---	---	---	---
50 mm	100	95-100	100	---	---	---	---
37.5 mm	90-100	---	95-100	100	---	---	---
25.0 mm	20-55	35-70	---	95-100	100	---	---
19.0 mm	0-15	---	35-70	---	90-100	100	---
12.5 mm	---	10-30	---	25-60	---	90-100	100
9.5 mm	0-5	---	10-30	---	20-55	40-70	90-100
4.75 mm	---	0-5	0-5	0-10	0-10	0-15	20-55
2.36 mm	---	---	---	0-5	0-5	0-5	5-30
1.18 mm	---	---	---	---	---	---	0-10
0.300 mm	---	---	---	---	---	---	0-5

Table 1E -- Required Grading, Graded Coarse Aggregates (English)

Standard Stone Size	#4	#357	#467	#57	#67	#7	#89
Min to Max	3/4 in to 1-1/2 in	No. 4 to 2 in	No. 4 to 1-1/2 in	No. 4 to 1 in	No. 4 to 3/4 in	No. 4 to 1/2 in	No. 16 to 3/8 in
Sieve Size	Percentage by Weight Passing						
2-1/2 in	---	100	---	---	---	---	---
2 in	100	95-100	100	---	---	---	---
1-1/2 in	90-100	---	95-100	100	---	---	---
1 in	20-55	35-70	---	95-100	100	---	---
3/4 in	0-15	---	35-70	---	90-100	100	---
1/2 in	---	10-30	---	25-60	---	90-100	100
3/8 in	0-5	---	10-30	---	20-55	40-70	90-100
No. 4	---	0-5	0-5	0-10	0-10	0-15	20-55
No. 8	---	---	---	0-5	0-5	0-5	5-30
No. 16	---	---	---	---	---	---	0-10
No. 50	---	---	---	---	---	---	0-5

SECTION 707 -- CEMENT MORTAR

Description

1.1 Cement mortar shall consist of either portland cement or masonry cement, mortar sand, and water.

Materials

2.1 Portland cement shall conform to 520.2.1.

2.2 Mortar sand shall meet the requirements of AASHTO M 45 except as shown in Table 1.

Table 1 - Gradation of Mortar Sand

Sieve Size	Percent by Weight Passing
2.36 mm (No. 8)	100
1.18 mm (No. 16)	60 - 100
0.300 mm (No. 50)	15 - 35
0.150 mm (No. 100)	2 - 15
0.075 mm (No. 200)	0 - 5

Note: In lieu of the above, fine aggregate graded in accordance with 520.2.2.2.2 may be used in mortar for mortar rubble masonry and with concrete blocks for catch basins and drop inlets.

2.3.1 Testing for impurities shall comply with AASHTO T 21. Results that are darker than the standard shall be cause for rejection, except as provided in 2.3.1.1.

2.3.1.1 Sand for mortar not conforming to 2.3.1 shall be tested in accordance with AASHTO T 71 and shall meet the requirements of 5.2.3 of AASHTO M 45.

2.4 Water shall meet the requirements of 520.2.5.

Proportions and Procedures

3.1 Mortar shall be composed of one part by volume of portland cement, except as specified in 3.4, and two parts by volume of damp loose mortar sand with water as necessary to obtain required consistency.

3.2 Hand mixing of mortar shall require thorough mixing of the dry cement and damp sand, in a clean, tight mortar box until the mixture is of a uniform color. Water shall be added in such quantity as to form a mortar having the desired consistency.

3.3 Machine mixing of mortar shall require mixing of the dry cement and damp sand, then adding water, to an approved mixer, for not less than three minutes to reach workability.

3.4 Cement for mortar in ashlar or for mortar squared stone masonry shall consist of portland cement only.

3.5 Mortars shall be used and placed in final position within two and one-half hours after mixing.

3.6 Mortar for bridge curbs shall meet the requirements of 609.2.5 and shall be used as specified under 609.3.1.7.

SECTION 708 -- PAINTS

708.01 Description. These specifications are intended to specify paints that will meet service requirements for highway construction.

Paint shall be homogeneous, free of contaminant, and of a consistency suitable for use in the capacity for which it is specified. Finished paint shall be well grounded, and the pigment shall be properly dispersed in the vehicle according to the requirements of the paint. The dispersion shall be of such nature that the pigment does not settle, does not cake or thicken in the container, and does not become granular or curdled. The paint shall be easily broken up with a paddle to form a smooth uniform product of the proper consistency and shall possess satisfactory properties in all respects which affect its application and curing.

The color shall match the established standard. The hiding power shall be sufficient to obtain complete hiding of the preceding coat with a single application when applied at normal spreading rates. The primer and intermediate coats shall dry with a dull gloss, and the finish coat shall dry with a semi gloss, unless otherwise specified.

In the following paint specifications, unless otherwise stated, all references to percentages refer to percentages by weight.

The final color of the paint specified for the work shall conform to FED-STD-595B and the specific color number specified below. The Department may approve a manufacturer's standard color provided it is very similar to that specified and color chips are submitted for approval before the paint is shipped.

Federal Standard Colors

Color	Federal Color Number
Green	24272
Dark Brown	20045
Aluminum	17178
White	17925
Black	27038

708.02 Packaging. All paint furnished must be shipped in original, sealed, strong, new containers having a capacity of not more than 18.9 L (5 gal) each. The containers shall be equipped with a lever-type ring seal or a lug-type cover and wire bails. Each container shall be so filled that the net weight of the material in the can is the product of the weight per liter (gallon) determined at 24 to 27 °C (75°F-80°F) and the specified liter (gallon) capacity of the can.

All containers of paint shall be clearly labeled with the following information:

New Hampshire Paint Number, Name, and Color
Name of Product
Lot and Batch Number
Date of Manufacture
Volume and Weight of Contents
Volatile Organic Compounds (VOC) Contents
Instructions for opening, mixing, thinning and applying the paint
Names and Address of Manufacturer

708.03 Approval, Sampling and Testing. The Contractor shall submit the complete paint system in writing to the Department for approval prior to use on the project. The Engineer shall be furnished with a Certificate of Compliance and Material Data Sheet for all paint used for shop coats prior to or upon delivery of painted structural steel to the project. (See 106.04.)

The paint will be sampled by lot for testing by the Department to insure compliance with material specifications prior to use. The material may be sampled either at the point of manufacture or application. Samples of paint furnished for field use shall be submitted at least ten working days before application, in order to allow the Engineer time for testing and accepting the paint. The Engineer may permit application of the paint in a shorter time upon approval of the manufacturer's Certificate of Compliance by the Bureau of Materials & Research.

Unless otherwise provided, the materials entering into the composition of the paint shall conform to the requirements of the applicable ASTM and AASHTO standards and FSS covering such materials. Testing shall be in accordance with the latest test methods of the ASTM and AASHTO standards and FED-STD-141C NOT 2. However, the Department reserves the right to make use of any information or methods of testing to determine the quality of paint and paint materials.

708.04 Raw Material Requirements. Unless otherwise stated, raw materials shall conform to the latest revision of the applicable AASHTO, ASTM and SSPC standards and specifications and specifically the following:

Raw Linseed Oil	ASTM D 234
Boiled Linseed Oil	ASTM D 260
Turpentine	ASTM D 13
Volatile Mineral Spirits	ASTM D 235
Varnish, Aluminum Paint	FSS TT-V-81G
Alkyd Resin Solution, Type I	FSS TT-R-266D
Alkyd Resin Solution, Type III	FSS TT-R-266D

708.05 Identification. To provide a means of identification, the applicable number and name taken from the following list, unless otherwise specified, shall be printed on the label.

Traffic Paints

NH 4.11	White Bead Binder*
NH 4.12	Yellow Bead Binder*
NH 4.13	Glass Spheres for Traffic Paint

* Specifications will be furnished if required.

NH 4.11 Ready-Mixed White Traffic Paint
NH 4.12 Ready-Mixed Yellow Traffic Paint

1.1 General. This specification covers ready-mixed 100% acrylic type, low VOC, fast drying, white or yellow waterborne traffic paint that can be used as a base for reflective spheres, or for use as a plain non-reflective paint. The paint shall be suitable for either bituminous or concrete surfaces.

1.2 The paint shall be formulated and processed specifically for service as a binder for reflective spheres, in such a manner as to produce maximum adhesion, refraction, and reflection and a highly weather resistant traffic line. Any capillary action of the paint shall not be such as to cause complete coverage of the spheres.

1.3 The paint shall dry on a road surface to a strongly adherent film that will not turn dark in sunlight or show appreciable discoloration with age. It shall be easily and uniformly applied with mechanical line-marking equipment and shall meet the opacity (contrast ratio) properties specified herein

2.1 Paint. Paint shall be 100% acrylic, with or without methanol, rated non-combustible with the composition complying with the following:

White Traffic Paint

Property	Test Method	Requirements
Binder	ASTM D 2621 Infrared Analysis	100 % Acrylic
Polymer Emulsion within Binder	NH DOT C1	Rohm and Haas FT3427 or approved equivalent.
Titanium Dioxide, Rutile Type II	ASTM D 1394	120 g/l (1 lb./gal.) Min.
Pigment, by weight	ASTM D 3723	58% Min. to 62% Max.
Total non-volatile	ASTM D 2697	76% Min. by weight 62% Min. by volume
Total non-volatile in vehicle	ASTM D 2697	42% Min. by weight
Lead	ASTM D 3335	0.06% Max.
VOC	ASTM D 3960	150 g/l (1.25 lb./gal.) Max.
Theoretical Weight	ASTM D 1475	1678 $\pm$ 36 g/l (14.0 $\pm$ 0.3 lb./gal.)
pH		9.6 Min.
Flash Point (Close Cup)		> 60 °C (140 °F)
Color White	Without spheres a minimum of 24 hours after application	Fed-Std-595B No. 37886

Yellow Traffic Paint

Property	Test Method	Requirements
Binder	ASTM D 2621 Infrared Analysis	100 % Acrylic
Polymer Emulsion within Binder	NH DOT C1	Rohm and Haas FT3427 or approved equivalent. Pigment - Yellow #65 or #75
Titanium Dioxide, Rutile Type II	ASTM D 1394	24 g/l (0.2 lb./gal.) Min.
Pigment, by weight	ASTM D 3723	58% Min. to 62% Max.
Total non-volatile	ASTM D 2697	76% Min. by weight 62% Min. by volume
Total non-volatile in vehicle	ASTM D 2697	42% Min. by weight
Lead	ASTM D 3335	0.06% Max.
VOC	ASTM D 3960	150 g/l (1.25 lb./gal.) Max.
Theoretical Weight	ASTM D 1475	1618 $\pm$ 36 g/l (13.5 $\pm$ 0.3 lb./gal.)
pH		9.6 Min.
Flash Point (Close Cup)		> 60 °C (140 °F)
Color Yellow	Without spheres a minimum of 24 hours after application	Fed-Std-595B No. 33538

2.2 In addition, all traffic paint shall comply with the following requirements:

Property	Test Method	Requirements
Viscosity (Krebs Units)	ASTM D 562	78 Min. to 95 Max. @ 25 °C (77 °F)
Fineness of Grind (North Standard)	ASTM D 1210	2 Min.
Drying Time	ASTM D 711 with wet film thickness of 15 mils	10 minutes Max. @ 25 °C (77 °F)
Flexibility	FSS TT-P-1952D, Section 4.5.5, using 1/2" mandrel bend	No Cracking or Flaking
Dry Opacity (contrast ratio)	ASTM D 2244	0.96 Min.
Daylight Reflectance	Federal Test Method No. 141c	85% Min. for White Paint 50% Min. for Yellow Paint
Bleeding (ratio)	FSS TT-P-1952D	0.97 Min.
Scrub Resistance	ASTM D 2486	Pass 300 cycles
Freeze-Thaw Stability	FSS TT-P-1952D	$\leq$ 10% change
Heat Stability (Krebs Units)	FSS TT-P-1952D	$\leq$ 10% change

Condition in Container: The paint shall show no livering, skinning, mold growth, putrification, corrosion of the container, or hard settling of the pigment in the container. Any settling shall be readily dispersed when stirred by hand with no persistent foaming.

No Track Time: Paint shall dry to a no tracking condition in no more than 3 minutes, the no tracking condition shall be determined by actual application on the pavement at a wet film thickness of 508 microns (20 mils) with white or yellow paint covered with glass beads at a rate of 960 grams per liter (8 pounds per gallon). The paint lines for this test shall be applied with the striping equipment operated so as to have the paint at temperatures between 20 - 35 °C (70 - 100 °F) at the spray orifice. This maximum tracking time shall not be exceeded when the pavement temperature varies from 10 °C (50 °F) to 50 °C (120 °F), and under humidity conditions of 80% or less providing that the pavement is dry. The no tracking time shall be determined by passing over the paint line 3 minutes after paint application, in a simulated passing maneuver at a constant speed of 48 to 64 kilometers per hour (30 to 40 miles per hour) with a passenger car. A line showing no visual deposition of the paint to the pavement surface when viewed from a distance of approximately 15.3 meters (50 feet) from the point where the test vehicle has crossed the line shall be considered as showing no tracking and conforming to the requirement for field drying conditions. This field dry time test shall be used for production samples only.

Dry Through (Early Washout): A sample of 15 mil wet film thickness paint placed immediately in a humidity chamber maintained at 22.5 °C $\pm$ 0.5 °C (72.5 °F $\pm$ 2.5 °F) and 90% $\pm$ 3% relative humidity shall have a "dry-through" time less than or equal to the specifier's laboratory reference paint film tested in accordance with ASTM D 1640, except that the pressure exerted will be the minimum needed to maintain contact between the thumb and film.

2.3 Material Safety Data Sheets (OSHA Form 20 or equivalent) pertinent to all materials in this product shall be within the striping vehicle.

NH 4.13 Glass Spheres for Traffic Paints

1. General. The glass spheres shall be clean, moisture-resistant, water white, transparent, and free from milkiness, pits, and excessive air bubbles, and they shall meet the requirements of AASHTO M 247.

SECTION 711 -- PREFORMED RETROREFLECTIVE PAVEMENT MARKING TAPE

Description

1.1 Description. Preformed retroreflective pavement marking tape shall be either removable or non-removable as specified. Removable tape shall be capable of being removed intact or in large strips. Non-removable tape shall be designed to remain in place.

1.2 General. Tape shall consist of glass spheres of a high optical quality imbedded into a binder on a suitable backing that is pre-coated with a pressure-sensitive adhesive. The spheres shall be of uniform gradation and shall be distributed evenly over the surface of the tape. The color of the tape shall conform to FHWA color standards for pavement markings and shall be readily visible when viewed under automotive headlights at night.

1.2.1 The marking tape, when applied in accordance with the manufacturer's recommended procedures, shall be weather resistant and shall show no appreciable fading, lifting, or shrinkage during the useful life of the marking. The tape, as applied, shall be of good appearance and free of cracks, and the edges shall be true, straight, and unbroken.

Materials

2.1 Short Term Pavement Marking Tape, Removable.

2.1.1 Composition. The removable preformed pavement marking tape shall not contain metallic foil and shall consist of a mixture of high quality polymeric materials and pigments, with glass beads throughout the pigmented portion of the film, and a retroreflective layer of beads bonded to the top surface. The films shall be precoated with a pressure-sensitive adhesive. A non-metallic medium shall be incorporated to facilitate removal.

2.1.2 General. The glass beads shall not be easily removed when the material surface is scratched with a thumbnail. The tape shall be precoated with a pressure-sensitive adhesive and shall be capable of adhering to hot bituminous pavement in accordance with the manufacturer's instructions without the use of heat, solvents, or other additional adhesive means. The tape shall be immediately ready for traffic after application.

2.1.3 Retroreflectance. The white and yellow tapes shall have the following initial minimum retroreflectance values at 0.2 and 0.5 degree observation angles and 86.0 degree entrance angle as measured in accordance with the testing procedure of FED-STD-370. The photometric quantity to be measured shall be specific luminance (SL) and shall be expressed as millicandelas per square meter per lux (millicandelas per square foot per footcandle). The test distance shall be 15.24 m (50 ft), and the sample size shall be a 0.61 by 0.76 m (2.0 by 2.5 ft) rectangle. The angular aperture of both the photoreceptor and light projector shall be six minutes of arc. The reference center shall be the geometric center of the sample, and the reference axis shall be taken perpendicular to the test sample.

	White		Yellow	
Observation Angle [degrees]	0.2	0.5	0.2	0.5
SL [mcd/m^2/lx] ([med/ft^2/fc])	1770	1270	1310	820

2.1.4 Adhesion. The manufacturer shall be required to demonstrate that the properly applied pavement marking tape adheres to the roadway under climatic and traffic conditions normally encountered in the construction work zone.

2.1.5 Skid resistance. The surface of the markings shall provide an initial minimum skid resistance value of 50 BPN when tested in accordance with ASTM E 303. The acronym BPN is defined in ASTM E 303.

2.1.6 Removability. The marking tape shall be removable from asphalt and portland cement concrete intact or in large pieces, either manually or with a roll up device, at temperatures above 4 °C (40 °F) without use of heat, solvents, grinding, or blasting. The

manufacturer shall be able to show that the marking film has met this requirement after the following minimum traffic exposure based on transverse test decks with rolling traffic:

(a)	Time in Place:	632 days
(b)	ADT per Lane:	9 000 (23 percent trucks, 3.5 axles per unit)
(c)	Minimum Axle Hits:	13 000 000

2.2 Short Term Pavement Marking Tape, Non-Removable.

2.2.1 Composition. The non-removable preformed pavement marking tape shall consist of retroreflective films on a conformable backing, precoated with a pressure-sensitive adhesive. This tape shall not be readily removed and shall be intended to be obliterated by over-paving or removal of pavement on which it is placed.

2.2.2 General. The glass beads shall not be easily removed when the material surface is scratched with a thumbnail. The tape shall be precoated with a pressure-sensitive adhesive and shall be capable of adhering to hot bituminous pavement in accordance with the manufacturer's instructions without the use of heat, solvents, or other additional adhesive means. The tape shall be immediately ready for traffic after application.

2.2.3 Retroreflectance. The white and yellow tapes shall have the following initial minimum retroreflectance values at 0.2 and 0.5 degree observation angles and 86.0 degree entrance angle as measured in accordance with the testing procedures of FED-STD-370. The photometric quantity to be measured shall be specific luminance (SL) and shall be expressed as millicandelas per square meter per lux (millicandelas per square foot per footcandle). The test distance shall be 15.24 m (50 ft), and the sample size shall be a 0.61 by 0.76 m (2.0 by 2.5 ft) rectangle. The angular aperture of both the photoreceptor and the light projector shall be six minutes of arc. The reference center shall be the geometric center of the sample, and the reference axis shall be taken perpendicular to the test sample.

	White		Yellow	
Observation Angle [degrees]	0.2	0.5	0.2	0.5
SL [mcd/m^2/lx] ([mcd/ft^2/fc])	1360	760	820	510

2.2.4 Adhesion. The manufacturer shall be required to demonstrate that the properly applied pavement marking tape adheres to the roadway under climatic and traffic conditions normally encountered in the construction work zone.

2.2.5 Skid resistance. The surface of the markings shall provide an initial minimum skid resistance value of 35 BPN when tested in accordance with ASTM E 303.

2.2.6 Abrasion resistance. Samples of the test material shall not wear through to the conformable backing surface in less than 125 cycles when tested in accordance with FED-STD-141C NOT 2, Method 6192, except using an H-22 wheel and 250 g load.

SECTION 716 -- SPECIFICATIONS FOR THE WELDING OF ALUMINUM ALLOYS FOR HIGHWAY STRUCTURES

1. General.

1.1 Description. These specifications apply to the welding of aluminum alloys used in bridge railing, structural supports for highway signs, luminaires, traffic signals, and the like.

1.2 Specifications.

1.2.1 The welding terms used in these specifications shall be interpreted in accordance with the definitions given in the latest edition of Welding Terms and Definitions, ANSI/AWS A3.0.

1.2.2 The welding symbols used on the plans will be those shown in the latest edition of Symbols for Welding, Brazing and Nondestructive Examination, ANSI/AWS A2.4. Special conditions will be fully explained by added notes or details.

1.2.3 The welding of aluminum bridge railing shall conform to Section 10 of the ANSI/AWS D1.2 "Structural Welding Code – Aluminum" including Part E "Workmanship Class II Structures". The fabrication and erection of bridge railing shall conform to Section 6 of the Specifications for Aluminum Structures, published by the Aluminum Association.

1.2.4 The welding of aluminum sign supports, luminaires, and traffic signals shall conform to Section 10 of the ANSI/AWS D1.2 "Structural Welding Code – Aluminum" including Part D "Workmanship Class I Structures".. The fabrication and erection of aluminum sign supports, luminaires, and traffic signals shall conform to the requirements of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. Special consideration may be given to certain support structures, which may be fabricated according to the provisions of 1.2.3.

2. Base Metals.

2.1 The aluminum alloys to be welded under these specifications may be any of the following alloy designations:

Wrought non-heat-treatable alloys
- Alloy 3003
- Alloy 3004
- Alloy 5052
- Alloy 5083
- Alloy 5086
- Alloy 5456

Wrought heat-treatable alloys
- Alloy 6061
- Alloy 6063

Cast heat-treatable alloy
- Alloy 356.0

2.2 Material used for permanent backing shall be at least equivalent in weldability to the base metal being welded.

3. Welding Processes.

3.1 These specifications include provisions for welding by the gas metal-arc process and the gas tungsten-arc process. Other processes may not be used except as permitted.

4. Filler Metal.

4.1 Bare wire electrodes for use with the gas metal-arc process and welding rods for use with the gas tungsten-arc process shall conform to the requirements of the latest edition of Specification for Bare Aluminum and Aluminum Alloy, Welding Electrodes and Rods, ANSI/AWS A5.10.

4.2 Tungsten electrodes for the gas tungsten-arc process shall conform to the requirements of the latest edition of Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding, ANSI/AWS A5.12.

4.3 Filler metals to be used with particular base metals shall be as shown in Table 1. Other filler metals may be used as approved.

Table 1 - Filler Metal Guide for Gas Shielded Arc Welding

Base Metals	Filler Metal
3003 to 3003	ER1100
3004 to 3004	ER4043
5052 to 5052	ER5654*
5083 to 5083	ER5183*
5086 to 5086	ER5356*
5456 to 5456	ER5556*
6061 to 6061	ER4043*
6063 to 6063	ER5356*
356.0 to 6061	ER4043
356.0 to 6063	ER4043

* ER5183, ER5356, and ER5556 may be used interchangeably for these base metals.

4.4 Filler metals shall be kept covered and stored in a dry place at relatively uniform temperatures. Original rod or wire containers shall not be opened until ready for use. Rod and wire shall be free of moisture, lubricant, or other contaminants. Spools of wire temporarily left unused on the welding machine shall be kept covered to avoid contamination by dirt and grease collecting on the wire. If a spool of wire is to be unused for more than a short length of time, the spool shall be returned to the carton, and the carton shall be tightly resealed.

5. Shielding Gases.

5.1 Shielding gases shall be welding grade or better.

5.2 Shielding gas for gas metal-arc welding shall be argon, helium, or a mixture of the two (at least 50 percent helium).

5.3 Shielding gas for gas tungsten-arc welding done with alternating current shall be argon.

5.4 Shielding gas for gas tungsten-arc welding done with direct current, straight-polarity, shall be helium.

5.5 Hoses used for shielding gases shall be made of synthetic rubber or plastic. Natural rubber hoses shall not be used. Hoses that have been previously used for acetylene or other gases shall not be used.

6. Preparation of Materials.

6.1 Joint details shall be in accordance with design requirements and detail drawings. The locations of joints shall not be changed without approval.

6.2 Edge preparation shall be by sawing, machining, clipping, or shearing. Gas tungsten-arc or gas metal arc cutting may also be used. Cut surfaces shall meet the ANSI surface roughness rating value of 1000. Oxygen cutting shall not be used.

6.3 Surfaces and edges to be welded shall be free from fins, tears, and other defects which would adversely affect the quality of the weld.

6.4 Dirt, grease, forming or machining lubricants, or any organic materials shall be removed from the areas to be welded by cleaning with a suitable solvent or by vapor degreasing.

6.5 On all edges and surfaces to be welded, the oxide shall be removed just prior to welding by wire brushing or by other mechanical methods, such as rubbing with steel wool or abrasive cloth, scraping, filing, rotary planing, or sanding. If wire brushing is used, the brushes shall be made of stainless steel. Hand or power driven wire brushes which have been used on other materials shall not be used on aluminum.

6.6 Where mechanical methods of oxide removal are found to be inadequate, a standard chemical method shall be used. Welding shall be done within 24 hours after chemical treatment.

6.7 When gas tungsten-arc welding with direct current, straight polarity, is being used, all edges and surfaces to be welded shall have the oxide removed by a standard chemical method.

6.8 Welding shall not be done on anodically treated aluminum unless the condition is removed from the joint area to be welded.

7. Welding Procedure.

7.1 All butt welds requiring 100 percent penetration, except those produced with the aid of backing, shall have the root of the initial weld chipped or machined out to sound metal before

welding is started from the second side. Butt welds made with the use of backing shall have the weld metal thoroughly fused with the backing. Where accessible, backing for welds that are subject to computed stress or that are exposed to view on the completed structure, and that are not otherwise parts of the structure, shall be removed and the joints ground or machined smooth. In tubular members, butt welds subjected to computed stresses shall be made with the aid of permanent backing rings or strips.

7.2 The procedure used for production welding of any particular joint shall be the same as used in the procedure qualification for that joint.

7.3 All welding operations, either shop or field, shall be protected from air currents or drafts so as to prevent any loss of gas shielding during welding. Adequate gas shielding shall be provided to protect the molten metal during solidification.

7.4 The work shall be positioned for flat position welding whenever practicable.

7.5 In both shop and field, all weld joints shall be dry at the time of welding.

7.6 The size of the electrode, voltage, amperage, welding speed, gas or gas mixture, and gas flow rate shall be suitable for the thickness of the material, design of joint, welding position, and other circumstances attending the work.

7.7 Gas metal-arc welding shall be done with direct current, reverse polarity.

7.8 Gas tungsten-arc welding shall be done with alternating current or with direct current, straight polarity.

7.9 When the joint to be welded requires specific root penetration, the Contractor shall make a sample joint and a macroetched cross-section of the weld to demonstrate that the joint welding procedure to be used attains the required root penetration. The sample joint shall have a length of at least 300 mm (1 ft) and shall be welded with the electrode, polarity, amperage, voltage, speed, gas mixture, and gas flow rate that are proposed to be used in production welding. The Engineer, at his discretion, may accept evidence on record in lieu of the preceding test.

7.10 Where preheat is needed, the temperature of preheat shall not exceed 175 °C (350 °F) for heat-treated alloys and 315 °C (600 °F) for non-heat-treated alloys. The temperature shall be measured by temperature-indicating crayons or by pyrometric equipment. Heat-treated alloys shall not be held at the maximum preheat temperature or at temperatures near the maximum for more than 30 minutes.

8. Weld Quality.

8.1 Regardless of the method of inspection, the acceptance or rejection of welds shall be determined by the following conditions:

(a) Cracks in welds or adjacent base metal will not be acceptable.
(b) Copper inclusions will not be acceptable.
(c) Porosity in excess of that permitted by Section 3 and Section 10 of the ANSI/AWS D1.2 “Structural Welding Code – Aluminum” will not be acceptable.

(d) Lack of fusion, incomplete penetration, or tungsten or oxide inclusion will be acceptable only if small and well dispersed.

8.2 Undercut shall not be more than 0.25 mm (0.01 in) deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than 0.80 mm (1/32 in) deep when its direction is parallel to the primary stress in the part that is undercut.

8.3 No overlap shall be allowed.

8.4 All craters shall be filled to the full cross-section of the welds.

8.5 Welds having defects greater then the levels of acceptance specified above shall be considered as rejected unless corrected in accordance with 716.10.

9. Inspection.

9.1 To determine compliance with Section 7, all welds shall be visually inspected, and in addition, all welds subject to computed stress shall be inspected by the dye penetrant method except as specified in 9.4.

9.2 For truss-type highway sign structures, the dye penetrant method shall be used on butt welds in columns and main chord members, on fillet welds connecting columns to bases and main chord members, including the associated flanges, gussets, or main load carrying brackets or members, and also on fillet welds connecting flanges to the main truss chord members. On pole type and common light standards, the dye penetrant method shall be used on butt welds in columns and on fillet welds connecting columns to bases.

9.3 The dye penetrant tests shall be performed in accordance with the requirements of ASTM E 165, Method B, Procedures B-2 or B-3.

9.4 Dye penetrant inspection may be omitted provided that the Inspector examines each layer of weld metal with a magnifier of 3X minimum before the next successive layer is deposited.

10. Corrections.

10.1 In lieu of rejection of an entire piece or member containing welding that is unacceptable, the corrective measures listed below may be permitted by the Engineer, whose approval shall be obtained prior to making each repair.

10.2 Defective welds shall be corrected by removing and replacing the entire weld, or as follows:

(a) Cracks in welds of base metal: Determine the full extent of the crack by the dye penetrant method or other positive means, then remove the crack throughout its length and depth, and reweld.

(b) Excessive porosity, lack of fusion: Remove the defective portions and reweld.

(c) Copper or tungsten inclusions: Remove the defective portions and reweld.

(d) Excessive concavity of the crater, undercut, or undersize weld: Clean and deposit additional weld metal.

(e) Overlap: Reduce by removal of excess weld metal.

10.3 The defective areas shall be removed by chipping or machining. Oxygen cutting shall not be used. Before rewelding, the joint shall be inspected to ensure that all of the defective weld has been removed. If dye penetrant has been used to inspect the weld, all traces of penetrant solutions shall be removed with solvent, water, heat, or other suitable means before rewelding.

11. Qualification of Procedures, Welders, and Welding Operators.

11.1 Joint welding procedures that are to be employed in executing contract work under these specifications shall be previously qualified by tests prescribed in Section 5 of the ANSI/AWS D1.2 "Structural Welding Code – Aluminum". The qualifications shall be at the expense of the Contractor. At the Engineer's discretion, evidence may be accepted of previous qualification of the joint welding procedures to be employed.

The fabrication shop shall maintain a file of certificates of qualification for its welders and welding operators and make the file available to the Engineer upon request. Each certificate of qualification shall state the name of the welder or welding operator, the name and title of the person who conducted the examination, the kind of specimens, the position of the welds, the results of the tests, and the date of the examination.

Upon request, the fabrication shop shall submit a letter of compliance to the Engineer listing by name all welders and welding operators employed on the fabrication of material for the project. The letter shall certify that these welders or welding operators have been prequalified and that they have been continuously engaged in gas metal-arc or gas tungsten-arc welding with no lapse in such employment in excess of six months since being prequalified.

11.2 All welders and welding operators to be employed under these specifications shall be previously qualified by tests as prescribed in Section 5 of the ANSI/AWS D1.2 "Structural Welding Code – Aluminum". At the Engineer's discretion, evidence may be accepted of previous qualification of the welders and welding operators to be employed. The same process and type of equipment that is required for execution of the construction work shall be used in qualifying welders and welding operators.

SECTION 718 -- RETROREFLECTIVE SHEETING

718.01 Description. Retroreflective sheeting shall consist of a retroreflective lens system having a smooth outer surface. When adhesive backing is used, the sheeting shall have a precoated adhesive on the backside protected by an easily removable liner. Types specified refer to levels of performance in terms of reflective intensity.

718.02 Color Requirements. The colors specified shall conform to the applicable requirements of AASHTO M 268 except modified as follows:

(a) Silver shall be an acceptable color designation for white.
(b) Table 2 shall be used for the Type II-A orange sheeting.
(c) Minimum reflectance limit for the color orange in Table 2 shall be 12.

The Engineer may accept colors by Certificate of Compliance or may require the Contractor to provide copies of laboratory test reports to substantiate compliance with contract color requirements.

718.03 Retroreflective Intensity. The retroreflective sheeting shall have minimum specific intensity per unit area (SIA) as shown in Tables 1, 2, 3, or 4 expressed as candelas per lux per square meter (candelas per footcandle per square foot).

718.04 Specular Gloss. The retroreflective sheeting shall have an 85 degree specular gloss of not less than 40 for Types II and II-A, and not less than 50 for Types III and IV, when tested in accordance with ASTM D 523.

718.05 Color Processing. The sheeting shall permit cutting color processing with compatible transparent and opaque process inks in accordance with the manufacturer's recommendation at temperatures of 16 to 38 °C (60 to 100 °F) and relative humidity of 20 to 80 percent. The retroreflective sheeting shall be heat resistant and shall permit force curing without staining of applied or unapplied sheeting at temperatures as recommended by the manufacturer. Color processing for Type III material shall be restricted to sheeting with heat activated adhesive backing unless otherwise recommended by the manufacturer.

718.06 Shrinkage. A 230 by 230 mm (9 by 9 in) retroreflective sheeting specimen with liner shall be conditioned a minimum of one hour at 22 °C (72 °F) and 50 percent relative humidity. The liner shall be removed, and the specimen shall be placed on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 hours, the specimen shall be measured to determine the amount of dimensional change. The retroreflective sheeting shall not shrink in any dimension more than 0.794 mm (1/32 in) in ten minutes nor more than 3.18 mm (1/8 in) in 24 hours.

718.07 Flexibility.

(a) Type II and Type II-A Sheeting Material: The sheeting, applied according to the manufacturer's recommendations to a clean, etched 0.51 by 50 by 200 mm (0.020 by 2 by 8 in) aluminum panel of alloy 6061-T6 conditioned a minimum of 48 hours and tested at 22 °C (72 °F) and 50 percent relative humidity shall be sufficiently flexible to show no cracking when bent around a 19 mm (3/4 in) mandrel.

(b) Type III and Type IV Sheeting Material: The sheeting, with the liner removed and conditioned for 24 hours at 22 °C (72 °F) and 50 percent relative humidity, shall be sufficintly flexible to show no cracking when slowly bent, in one second's time, around a 3.18 mm (1/8 in) mandrel with adhesive contacting the mandrel. Non-adhesive sheetings shall show no signs of cracking or crazing when flexed repeatedly over a 1.59 mm (1/16 in) mandrel to 180 degrees at 22 °C (72 °F).

718.08 Adhesive. The retroreflective sheeting shall include a pre-coated pressure-sensitive adhesive backing (Class 1) or a tack-free heat activated adhesive backing (Class 2) either of which may be applied without necessity of additional adhesive coats on either the retroreflective sheeting or application surface. The Class 1 adhesive shall be a pressure-sensitive adhesive of the aggressive tack type requiring no heat solvent or other preparation for adhesion to smooth clean surfaces. The Class 2 adhesive backing shall be a tack-free adhesive activated by applying

heat in excess of 79 °C (175 °F) to the material as in the heat-vacuum process of sign fabrication. The protective liner attached to the adhesive shall be removed by peeling without soaking in water or other solvents without breaking, tearing, or removing any adhesive from the backing. The protective liner shall be easily removed following accelerated storage for four hours at 71 °C (160 °F) under a weight of 17.2 kPa (2.5 psi). The adhesive backing of the retroreflective sheeting shall produce a bond to support a 0.794 kg (1.75 lb) weight for five minutes, without the bond peeling for a distance of more than 50 mm (2.0 in) when applied to a smooth aluminum surface.

718.09 Impact Resistance. Type II, Type II-A, and Type III retroreflective sheeting material, applied according to the manufacturer's recommendations to a cleaned, etched aluminium panel of alloy 6061-T6, 1.02 by 75 by 125 mm (0.04 by 3 by 5 in) and conditioned for 24 hours at 22 °C (72 °F) and 50 percent relative humidity, shall show no cracking when the face of the panel is subjected to an impact of a 0.91 kg (2.0 lb) weight with a 16 mm (5/8 in) rounded tip, dropped from a 1.13 N•m (10 in-lb) setting on a Gardner Variable Impact Tester, 1G-1120. For Type IV material a 11.3 N•m (100 in-lb) setting should be used.

718.10 Accelerated Weathering. When applied in accordance with recommended procedures, the retroreflective material shall be weather resistant and, following cleaning in accordance with manufacturer's recommendations, shall show no appreciable discoloration, cracking, blistering, or dimensional change. Following exposure, the panels shall be washed with a five percent HCl solution for 45 seconds, rinsed thoroughly with clean water, blotted with a soft clean cloth, brought to equilibrium at standard conditions, and tested. The panels shall have not less than the percent of the minimum specific intensity per unit area (SIA) specified in the table below when subjected to accelerated weathering in accordance with ASTM G 23, Type E or EH weatherometer with the humidifier off.

Type of Material	Hours Tested	Minimum Specific Intensity Per Unit Area
II	1000	50 percent of Table 1
II-A	2200*	65 percent of Table 2
III	2200*	80 percent of Table 3
IV	250	50 percent of Table 4

* For orange material having glass bead retroreflective elements, the hours tested shall be 500.

718.11 Intended Use. The retroreflective sheeting specified herin is intended for use on surfaces of highway signs and other traffic control devices to ensure optimum visibility by day, and at night when exposed to a light source, and whether dry or totally wet by rain.

718.12 Reference Source. This specification is taken from, and is intended to conform to, Federal Highway Administration publication, Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects.

Table 1 -- Minimum Specific Intensity Per Unit Area (SIA)
Candelas Per Lux Per Square Meter (Candelas Per Footcandle Per Square Foot)
Type II Sheeting

Observation Angle (°)	Entrance Angle (°)	White	Red	Orange	Brown	Yellow	Green	Blue
0.2	-4	70	14.5	25.0	2.0	50	9.0	4.0
0.2	+30	30	6.0	7.0	1.0	22	3.5	1.7
0.5	-4	30	7.5	13.5	1.0	25	4.5	2.0
0.5	+30	15	3.0	4.0	0.5	13	2.2	0.8

Table 2 -- Minimum Specific Intensity Per Unit Area (SIA)
Candelas Per Lux Per Square Meter (Candelas Per Footcandle Per Square Foot)
Type II-A Sheeting

Observation Angle (°)	Entrance Angle (°)	White	Red	Orange	Brown	Yellow	Green	Blue
0.2	-4	140	30	60	5	100	30	10
0.2	+30	60	12	22	2	36	10	4
0.5	-4	50	10	20	2	33	9	3
0.5	+30	28	6	12	1	20	6	2

Table 3 -- Minimum Specific Intensity Per Unit Area (SIA)
Candelas Per Lux Per Square Meter (Candelas Per Footcandle Per Square Foot)
Type III Sheeting

A -- Glass Bead Retroreflective Element Material

Observation Angle (°)	Entrance Angle (°)	White	Red	Orange	Yellow	Green	Blue
0.2	-4	250	45	100	170	45	20.0
0.2	+30	150	25	60	100	25	11.0
0.5	-4	95	15	30	62	15	7.5
0.5	+30	65	10	25	45	10	5.0

B -- Prismatic Retroreflective Element Material

Observation Angle (°)	Entrance Angle (°)	White	Red	Orange	Yellow	Green	Blue
0.2	-4	250	45.0	100	170	45.0	20.0
0.2	+30	95	13.3	26	64	11.4	7.6
0.5	-4	200	28.0	56	136	24.0	18.0
0.5	+30	65	10.0	25	45	10.0	5.0

Table 4 -- Minimum Specific Intensity Per Unit Area (SIA)
(Candelas Per Lux Per Square Meter) (Candelas Per Footcandle Per Square Foot)
Type IV Sheeting

Observation Angle (°)	Entrance Angle (°)	White	Red	Orange	Yellow	Green	Blue
0.2	-4	250	35	70	170	30.0	20.0
0.2	+30	95	13.3	26	64	11.4	7.6
0.5	-4	200	28.0	56	136	24.0	18.0
0.5	+30	60	8.4	17	40	7.2	4.8

* Test samples are to be mounted in accordance with manufacturer's recommendation.